AMENDMENT TO THE CLAIMS

This listing of claims will replace all prior versions, and listings, of claims in the application:

LISTING OF CLAIMS

1 – 120 (cancelled)

R. 126

122
~~121~~. (new) A geometric pattern matching apparatus for refining a starting pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the apparatus comprising:

a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points, and information about the pattern boundary points; and

a run-time module adapted to:

receive the stored model pattern, the starting pose, and the run-time image;

detect in the run-time image a plurality of image boundary points; and

use the stored model pattern, the starting pose, and the plurality of image boundary points in a sequence of pose refinements to provide: a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image; an error value; an aggregate clutter value; and an aggregate coverage value.

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122
~~121~~. (new) The apparatus of claim ~~121~~, wherein the run-time module is also adapted to provide:

provide an evaluated image boundary point list that provides, for each of a plurality of said image boundary points, a numerical evaluation of the likelihood that the image boundary point was present in the stored model pattern.

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122
~~123~~. (new) The apparatus of claim ~~121~~, wherein the run-time module is also adapted to provide:

an evaluated pattern boundary point list that provides, for each of a plurality of said pattern boundary points, a numerical evaluation of the likelihood that the pattern boundary point was present in the run-time image.

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~~124~~. (new) The apparatus of claim ~~121~~, wherein the run-time module is also adapted to:

receive and use a coordinate transformation that maps points in an orthonormal coordinate system to points in the run-time image.

126 122
~~125~~. (new) The apparatus of claim ~~121~~, wherein the run-time module is also adapted to:

determine, using the starting pose and the model pattern, an evaluation of reliability of at least some of the plurality of image boundary points, and a corresponding position along a boundary of the model pattern corresponding to at least some of the plurality of image boundary points.

127 122
~~126~~. (new) The apparatus of claim ~~121~~, wherein parameters are used to help detect in the run-time image a plurality of image boundary points.

128 122
~~127~~. (new) The apparatus of claim ~~121~~, wherein parameters are used to facilitate the sequence of pose refinements.

129 122
~~128~~. (new) The apparatus of claim ~~121~~, wherein the error value is an rms error value.

130 122
~~129~~. (new) The apparatus of claim ~~121~~, wherein the information about the pattern boundary points is a vector-valued function of position within a region that includes the pattern boundary points.

131 130
~~130~~. (new) The apparatus of claim ~~129~~, wherein the vector-valued function relates a plurality of at least two-dimensional positions to a plurality of respective displacement vectors.

132 131
~~131~~. (new) The apparatus of claim ~~130~~, wherein each displacement vector indicates a distance and direction from a two-dimensional position to a nearest point along a pattern boundary that includes pattern boundary points.

133 130
~~132~~. (new) The apparatus of claim ~~129~~, wherein the vector-valued function relates a plurality of two-dimensional positions and associated directions to a plurality of respective displacement vectors.

134
~~133~~. (new) A geometric pattern matching apparatus for refining a starting pose of an object in a run-time image, the object having an expected shape and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the apparatus comprising:

a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points, and information about the pattern boundary points;

a feature detector adapted to detect in the run-time image a plurality of image boundary points; and

a sequential pose refinement module adapted to use the stored model pattern, the starting pose, and the plurality of image boundary points in a sequence of pose refinements to provide:

a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image;

an error value;

an aggregate clutter value; and

an aggregate coverage value.

135 ~~134~~. (new) The apparatus of claim ~~133~~ 134, wherein the sequential pose refinement module receives and uses a coordinate transformation that maps points in an orthonormal coordinate system to points in the run-time image.

136 ~~135~~. (new) The apparatus of claim ~~133~~ 134, wherein the sequential pose refinement module also being adapted to provide an evaluation of reliability of at least some of the plurality of image boundary points, and a corresponding position along a boundary of the model pattern corresponding to at least some of the plurality of image boundary points.

137 ~~136~~. (new) The apparatus of claim ~~133~~ 134, wherein the sequential pose refinement module also being adapted to provide an evaluated image boundary point list that provides, for each of a plurality of said image boundary points, a numerical evaluation of the likelihood that the image boundary point was present in the stored model pattern.

138 ~~137~~. (new) The apparatus of claim ~~133~~ 134, wherein the sequential pose refinement module also being adapted to provide an evaluated pattern boundary point list that provides, for each of a plurality of said pattern boundary points, a numerical evaluation of the likelihood that the pattern boundary point was present in the run-time image.

139 ~~138~~. (new) The apparatus of claim ~~133~~ 134, wherein the feature detector uses parameters to help detect in the run-time image the plurality of image boundary points.

140 ~~139~~. (new) The apparatus of claim ~~133~~ 134, wherein the sequential pose refinement module uses parameters to facilitate the sequence of pose refinements.

141 ~~140~~. (new) The apparatus of claim ~~133~~ 134, wherein the error value is an rms error value.

142 ~~141~~. (new) The apparatus of claim ~~133~~ 134, wherein the information about the pattern boundary points is a vector-valued function of position within a region that includes the pattern boundary points.

143 ~~142~~. (new) The apparatus of claim ~~141~~ 142, wherein the vector-valued function relates a plurality of at least two-dimensional positions to a plurality of respective displacement vectors.

144 ~~143~~. (new) The apparatus of claim ~~142~~ 143, wherein each displacement vector indicates a distance and direction from a two-dimensional position to a nearest point along a pattern boundary that includes pattern boundary points.

145 ~~144~~. (new) The apparatus of claim ~~141~~ 142, wherein the vector-valued function relates a plurality of two-dimensional positions and associated directions to a plurality of respective displacement vectors.

146 ~~145~~. (new) A geometric pattern matching method for refining a starting pose of an object in a run-time image, the object having an expected object boundary and a true pose in the run-time image, the starting pose representing an initial estimate of the true pose of the object in the run-time image, the method comprising:

providing model pattern boundary information of a model pattern of the object;

providing an image boundary description of an object boundary in the run-time image; and

using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements to provide at least a refined pose, the refined pose representing a refined estimate of the true pose of the object in the run-time image.

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~~146~~. (new) The method of claim ~~145~~ 146, wherein providing an image boundary description of a boundary in the run-time image includes:

148 detecting in the run-time image a plurality of image boundary points.

~~147~~. (new) The method of claim ~~145~~ 146, wherein providing an image boundary description of a boundary in the run-time image includes:

149 synthetically generating a plurality of image boundary points.

~~148~~. (new) The method of claim ~~145~~ 146, wherein using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements further provides an error value.

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~~149~~. (new) The method of claim ~~145~~ 146, wherein using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements further provides an aggregate clutter value.

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~~150~~. (new) The method of claim ~~145~~ 146, wherein using the model pattern boundary information, the starting pose, and the image boundary description in a sequence of pose refinements further provides an aggregate coverage value.

152

~~151~~. (new) The method of claim ~~145~~ 146, wherein providing model pattern boundary information of a model pattern of the object includes:

providing a stored model pattern, the stored model pattern including a geometric description of the expected shape of the object, the geometric description including a plurality of pattern boundary points, and information about the pattern boundary points.

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~~152~~. (new) The method of claim ~~151~~ 152, wherein the information about the pattern boundary points is a vector-valued function of position within a region that includes the pattern boundary points.

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~~153~~. (new) The method of claim ~~152~~ 153, wherein the vector-valued function relates a plurality of at least two-dimensional positions to a plurality of respective displacement vectors.

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~~154~~. (new) The method of claim ~~153~~ 154, wherein each displacement vector indicates a distance and direction from a two-dimensional position to a nearest point along a pattern boundary that includes pattern boundary points.

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~~155~~. (new) The method of claim ~~152~~ 153, wherein the vector-valued function relates a plurality of two-dimensional positions and associated directions to a plurality of respective displacement vectors.

157 146
~~156.~~ (new) The method of claim ~~145~~, wherein providing model pattern boundary information of a model pattern of the object includes:

158 providing a geometric description of the expected shape of the object.

~~157.~~ (new) The method of claim ~~156~~, wherein the geometric description includes
159 a plurality of pattern boundary points.

~~158.~~ (new) The method of claim ~~145~~, wherein providing model pattern boundary information of a model pattern of the object includes:

providing a plurality of pattern boundary points, and information about
160 the pattern boundary points.

~~159.~~ (new) The method of claim ~~151~~, wherein each pattern boundary point of the plurality of pattern boundary points includes:

161 position information and direction information.

~~160.~~ (new) The method of claim ~~146~~, wherein each image boundary point obtained by detecting in the run-time image a plurality of image boundary points includes:

position information and direction information.